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Source Testing for Particulate Emissions From the Pyrolysis Furnace at Hamblin Engineering Company, Winnipeg, Manitoba

1985

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Workplace Safety and Health.

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ABSTRACT

During June and August 1985, two particulate emission surveys were conducted on the pyrolysis furnace at Hamblin Engineering Company, 320 Osborne St., Winnipeg, Manitoba. During the first survey, the average particulate concentration, at mean stack CO_2 value was 0.07 grams per dry standard* cubic metre (g/dscm). When mean stack CO_2 values were corrected to 12%, the average particulate concentration increased to 0.16 g/dscm. Immediately after the testing was completed in June the stack was enlarged and operational procedures were changed. A follow-up survey in August revealed an average particulate concentration, at mean stack CO_2 value, of 0.06 g/dscm. When mean stack CO_2 values were corrected to 12%, the average particulate concentration increased to 0.53 g/dscm. The results of the second survey indicate that in its current configuration, the pyrolysis incinerator is in noncompliance with Manitoba Regulation 334/74, Section 3(1).

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*Temperature 20°C, pressure 760 mm Hg.

INTRODUCTION

A special furnace was constructed at Hamblin Engineering Company, 320 Osborne St., Winnipeg, to incinerate used rubber vehicle tires and various waste materials. As with other new incinerators this unit must comply with Manitoba Regulation 334/74, a regulation under the Manitoba Clean Environment Act respecting incinerators.

PROCESS DESCRIPTION

A specially designed pyrolysis furnace was constructed at Hamblin Engineering Company to dispose of waste materials and used vehicle tires. Pyrolysis is a thermal conversion process where wastes are chemically changed in an oxygen reduced area rather than being burned in an oxygen rich atmosphere. The breakdown products can either be condensed to form oils, tars etc. or used as a fuel source to make the incinerator self sustaining.

At Hamblin Engineering used vehicle tires are loaded into the primary chamber of the furnace and are ignited by a natural gas burner. Once the tires are smoldering the natural gas to the primary burner is turned off . A second natural gas burner heats up the afterburner chamber to the point where partially gasified combustion products and thermally altered tars and oils are completely burned. When the temperature in the afterburner reaches a predetermined point, the natural gas is turned off and the oils and tars released from the smoldering tires are burned to make the pyrolysis operation self sustaining. The exhaust gases from the primary chamber were fed along the outside of the furnace in a steel manifold that entered the secondary chamber near the natural gas burner. Heat is recovered from the exhaust gas by passing it through the walls and floor of the primary chamber before entering the chimney.

PROCESS SCHEDULE

Charging material for the 1985 emission tests was limited to used vehicle tires. The charging schedule is recorded below in Table 1.

TABLE 1 : PROCESS SCHEDULE AND TEST PERIODS

DATE	TIME	ITEM	TEST PERIOD
June 19, 1985	8:00 AM	6 tires charged	
			TEST 1 9:56 AM to 10:19 AM
	10:35 AM	7 tires charged	
			TEST 2 11:45 AM to 12:07 PM
			TEST 3 12:37 PM to 12:59 PM
August 19, 1985	10:11 AM	6 tires charged	
			TEST 4 10:19 AM to 11:53 AM
	10:27 AM	primary chamber reignited	
			TEST 5 12:54 PM to 2:50 PM
August 21, 1985	9:38 AM	8 tires charged	
			TEST 6 9:52 AM to 11:30 AM

TEST PROCEDURES

For tests 1 through 3 sampling was conducted from two 3 in. ports located on the east side of the 12 in. square stack. The sampling locations were 7.2 ft. (equivalent to 7.2 duct diameters) above the furnace and more than 2 ft. (in excess of 2 duct diameters) below the top of the stack. Two points were sampled along each traverse according to Environmental Protection Service (EPS) Method A specifications. The sample points, located at 3 and 9 in. respectively from the stack wall are depicted on a cross section of the stack in Figure 1. Sampling intervals were five minutes per point.

For tests 4 through 6 sampling was conducted from four 3 in. ports located on the north side of the 34 by 20 in. rectangular stack. The sampling locations were 21.2 ft. (equivalent to 7.5 duct diameters) above the furnace and 2.8 ft. (equivalent to 1 duct diameter) below the top of the stack. Four points were sampled along each traverse according to EPS Method A specifications. The sample points, located at 2.5, 7.5, 12.5 and 17.5 in. respectively from the stack wall are depicted on a cross section of the stack in Figure 2. Sampling intervals were five minutes per point.

Source emission testing was conducted according to EPS Method E. Figure 3 illustrates the particulate stack sampling train. The sample was drawn into a nozzle, through a 3 ft. stainless steel heated probe and into a miniature cyclone which removed particulate matter of greater than 10μ diameter. The sample was then passed through a Whatman 934 AH glass microfiber filter (supported by a

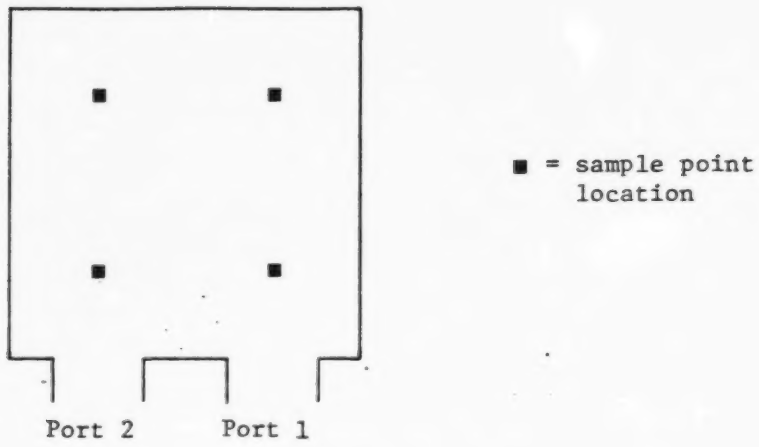


FIGURE 1. Cross Section of the 12" x 12" Stack Indicating Sample Point Locations.

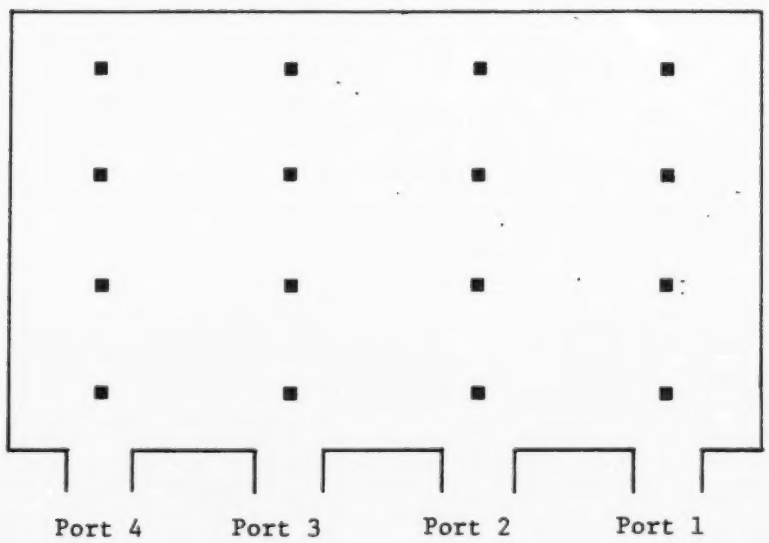


FIGURE 2. Cross Section of the 34" x 20" Stack Indicating Sample Point Locations.

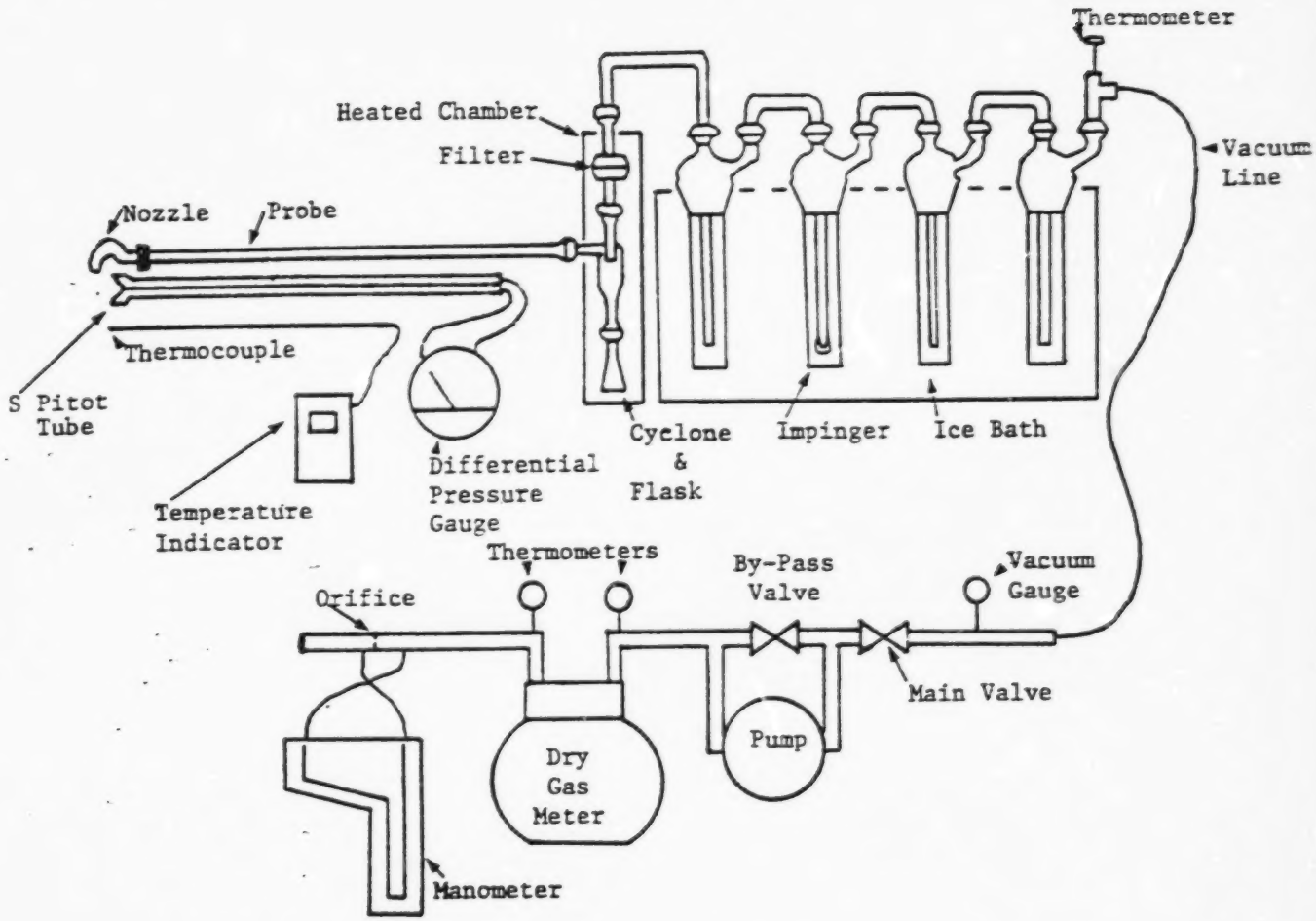


FIGURE 3. Particulate Stack Sampling Train

porous fritted glass disc), which removed particulate matter of 0.3μ diameter and greater. Both the cyclone and the filter were heated to prevent moisture from condensing at that point. The sample was then passed through four 500 ml Greenburg-Smith impingers connected in series in an ice bath. The first, third and fourth impingers had modified straight tips while the second which was of the standard design. The first and second impingers contained 100 ml of deionized water. The third impinger was initially empty while the fourth contained 200 grams of indicating silica gel to remove remaining moisture from the gas sample.

A Bendix Series 4500 Isokinetic Stack Sampler was used to extract the samples from the stack. Gas velocity in the stack was measured with an S type pitot tube and a Dwyer Magnehelic Differential Pressure Gauge (range 0 to .25" H_2O, minor division 0.005" H_2O). Dry gas meter and pitot tube calibration data sheets are located in Appendix A. A Hays-Republic Model 621A Gas Analyzer was used to determine CO_2, O_2 and CO content of the stack gas. Stack temperature was measured by a K type thermocouple.

After sample recovery from the stack train, samples were submitted to the W. M. Ward Technical Services Laboratory for gravimetric analyses of particulates.

The sampling team consisted of Kevin Reeve, Art Schultz and Tim Higham.

RESULTS

Important sampling parameters are summarized in Table 2. Refer to Appendices B and C respectively for velocity profiles and field data sheets.

Source emission data are summarized in Table 3. The analytical reports are located in Appendix D.

TABLE 2: SUMMARY OF SAMPLING PARAMETERS

TEST NUMBER	1	2	3
SAMPLING DATE	June 19, 1985	June 19, 1985	June 19, 1985
SAMPLING DURATION, minutes	20	20	20
SAMPLE VOLUME AT METER CONDITIONS, m^3	0.5146	0.3087	0.2962
SAMPLE VOLUME AT STD. CONDITIONS,* dscm	0.4836	0.2837	0.2698
AVE. GAS METER TEMPERATURE, °F	87	100	105
AVE. ORIFICE PRESSURE DROP, in. H_2O	2.76	0.95	0.88
STACK STATIC PRESSURE, in. H_2O	+0.03	+0.03	+0.03
AVE. STACK GAS TEMPERATURE, °F	462	546	554
AVE. STACK GAS VELOCITY, ft/s	19.4	22.7	22.2
ISOKINETIC FACTOR, %	104.7	106.4	103.8

*Standard Conditions are 20°C and 760 mm Hg

TABLE 2: (CONTINUED)

TEST NUMBER	4	5	6
SAMPLING DATE	Aug. 19, 1985	Aug. 19, 1985	Aug. 21, 1985
SAMPLING DURATION, minutes	80	80	80
SAMPLE VOLUME AT METER CONDITIONS, m^3	1.1698	1.0482	0.9105
SAMPLE VOLUME AT STD. CONDITIONS,* dscm	1.1048	0.9892	0.8753
AVE. GAS METER TEMPERATURE, °F	94	94	84
AVE. ORIFICE PRESSURE DROP, in. H_2O	0.90	0.71	0.56
STACK STATIC PRESSURE, in. H_2O	+0.03	+0.03	+0.03
AVE. STACK GAS TEMPERATURE, °F	371	389	423
AVE. STACK GAS VELOCITY, ft/s	10.1	9.1	8.3
ISOKINETIC FACTOR, %	100.3	100.1	101.4

*Standard Conditions are 20°C and 760 mm Hg

TABLE 3: SOURCE EMISSION SUMMARY

TEST NUMBER		1	2	3	AVERAGE*
STACK GAS COMPOSITION	CO_2	8	7	3.5	-
DRY BASIS, % BY VOLUME	O_2	13	14	16.5	-
	CO	0	0	0	-
STACK GAS MOISTURE, % BY VOLUME		6.8	1.7	7.4	-
Ms**, g/g-mole		29.09	28.78	28.39	-
AVERAGE STACK GAS VOLUMETRIC FLOW RATE, dscm/h		1030	1094	1065	1063
CONCENTRATION OF PARTICULATE IN THE STACK GAS, g/dscm	AT STACK CO_2	0.04	0.11	0.06	0.07
	AT 12% CO_2	0.07	0.20	0.20	0.16
EMISSION RATE OF PARTICULATE, kg/h		0.05	0.13	0.06	0.08

* For the 12" x 12" stack

** Molecular Weight of the Stack Gas on a Wet Basis

TABLE 3: (CONTINUED)

TEST NUMBER		4	5	6	AVERAGE*
STACK GAS COMPOSITION DRY BASIS, % BY VOLUME	CO_2	1.0	1.5	2.0	-
	O_2	19.0	18.9	19.3	-
	CO	0	0	0	-
STACK GAS MOISTURE, % BY VOLUME		5.2	4.2	4.4	-
Ms**, g/g-mole		28.35	28.54	28.60	-
AVERAGE STACK GAS VOLUMETRIC FLOW RATE, dscm/h		2897	2582	2253	2577
CONCENTRATION OF PARTICULATE IN THE STACK GAS, g/dscm:	AT STACK CO_2	0.07	0.05	0.06	0.06
	AT 12% CO_2	0.86	0.37	0.35	0.53
EMISSION RATE OF PARTICULATE, kg/h		0.21	0.12	0.13	0.15

* For the 34" x 20" stack

** Molecular Weight of the Stack Gas on a Wet Basis

DISCUSSION

The changes in incinerator design and operational procedures after test 3 significantly reduced the percentage of CO_2 in the flue gas. The most plausible cause for this is too much excess air entering the incinerator - which produces a significant change in the average particulate concentration when corrected to 12% CO_2.

CONCLUSION

The results of source emission tests 1, 2 and 3 indicate that during the first survey the average particulate emission was 0.16 g/dscm when corrected to 12% CO_2 or 0.07 g/dscm at mean stack CO_2 values. When corrected to 12% CO_2 the particulate emission was below the Manitoba Regulation 334/74, Section 3(1) limit of 0.23 g/dscm.

The results of source emission tests 4, 5 and 6 (which reflect changes in the incinerator design and operation) indicate that during the follow-up survey the average particulate emission was 0.53 g/dscm when corrected to 12% CO_2 or 0.06 g/dscm at mean stack CO_2 values. When corrected to 12% CO_2 the particulate emission was in noncompliance with Manitoba Regulation 334/74, Section 3(1).

SELECTED BIBLIOGRAPHY

1. REEVE, KEVIN E. Source Testing For Particulate Emissions From The Incinerator At Cara Operations Ltd., Winnipeg, Manitoba. Wpg., Mb: Manitoba Department of Environment and Workplace Safety and Health, 1983.

2. Standard Reference Methods For Source Testing: Measurement of Emissions Of Particulates From Stationary Sources. Ottawa, Ont: Environment Canada, Environmental Protection Service, 1974 (Report EPS 1-AP-74-1).

APPENDIX A: EQUIPMENT CALIBRATION DATA

DRY GAS METER & ORIFICE METER CALIBRATION SHEET

Lab No. 14'93 1/2

Dry Gas Meter S/N: Bendix 711030

Calibrated re Large Wet Test Meter

Atmospheric Pressure: 29.3 in Hg or 744.2 mm Hg

Calibrated by: Jim Pochopovich & Tim Higham

Ambient Temperature: 19.6°C ± 1.9 °C

Date: 23 May 85

Manometer Orifice ΔH (in. H_2O)	W.T.M. Volume Vw ($Ft.^3$)	Dry Gas Meter Reading Initial ($Ft.^3$)	Dry Gas Meter Reading Final ($Ft.^3$)	D.G.M. Volume Vd ($Ft.^3$)	Temperature W.T.M. Tw (°F.)	Temperature W.T.M. Tw (°C.)	Temperature D.G.M. Ti (°F.)	Temperature D.G.M. To (°F.)	Time θ (Min.:Sec.)	Time θ (Min.)	W.T.M. Manometer Δm (in. H_2O)	Partial Pressure Pr (mm. Hg)	W.T.M.:D.G.M. Ratio γ (—)	$\sqrt{\quad}$ (—)	Flowrate Q S.T.P. Qs ($Ft.^3$/min.)
0.505	3.0	90.345	93.433	3.088	63.3	17.4	106	77	7:50.83	7.8472	0.42	14.903	1.00103	0.56507	0.38351
0.505	4.0	95.511	99.649	4.138	63.4	17.4	106	78	10:29.49	10.4915	0.27	14.903	0.99711	0.56559	0.38336
0.505	3.0	100.687	103.793	3.106	63.5	17.5	107	78	7:52.74	7.8790	0.23	14.998	0.99699	0.56559	0.38271
1.00	4.0	105.872	110.021	4.149	63.5	17.5	110	80	7:20.54	7.3423	0.53	14.998	0.99766	0.79688	0.54857
1.00	4.0	111.058	115.213	4.155	63.6	17.6	110	80	7:21.34	7.3557	0.53	15.092	0.99591	0.79688	0.54735
1.00	4.0	116.257	120.413	4.156	63.6	17.6	110	80	7:21.68	7.3613	0.49	15.092	0.99577	0.79688	0.54699
1.52	4.0	122.491	126.656	4.162	63.6	17.6	113	81	5:57.69	5.9615	0.54	15.092	0.99649	0.98273	0.67571
1.51	4.0	127.705	131.877	4.172	63.6	17.6	114	82	5:57.88	5.9647	0.58	15.092	0.99581	0.98041	0.67655
1.52	4.0	132.914	137.090	4.176	63.7	17.6	113	82	5:57.97	5.9662	0.66	15.092	0.99355	0.98314	0.67609
2.02	5.0	141.268	146.487	5.219	63.8	17.7	116	82	6:31.24	6.5207	0.68	15.188	0.99480	1.13323	0.77206
2.02	5.0	147.527	152.761	5.234	63.8	17.7	115	83	6:31.42	6.5237	0.47	15.188	0.99247	1.13428	0.77348
2.01	5.0	153.803	159.027	5.224	63.9	17.7	116	83	6:31.40	6.5233	0.48	15.188	0.99507	1.13148	0.77338

Linear Regression: Intercept (b) 0.0102

Slope (K) 0.6708

Coefficient of Determination (r^2) 0.9993

$\overline{\gamma}$ = 0.9947 ± 0.0027

ΔHG = 2.0424

Comments:

#245 Rev. 9/24/85 JF/sm

DRY GAS METER & ORIFICE METER CALIBRATION SHEET

Lab No. 14193 2/2

Dry Gas Meter S/N: Bendix 711030

Atmospheric Pressure: 29.3 in hg = 744.2 mm hg

Ambient Temperature: 19.6 °C — 19.9 °C

Calibrated re: Large Wet Test Meter

Calibrated by: Jim Parkhurst & Jim Higham

Date: 23 May 85

Manometer Orifice ΔH (in. H_2O)	W.T.M. Volume Vw ($Ft.^3$)	Dry Gas Meter Reading Initial ($Ft.^3$)	Dry Gas Meter Reading Final ($Ft.^3$)	D.G.M. Volume Vd ($Ft.^3$)	Temperature W.T.M. Tw (°F.)	Temperature W.T.M. Tw (°C.)	Temperature D.G.M. Ti (°F.)	Temperature D.G.M. To (°F.)	Time t (Min.:Sec.)	Time t (Min.)	W.T.M. Manometer Δ m (in. H_2O)	Partial Pressure Pe (mm. Hg)	W.T.M.:D.G.M. Ratio γ (—)	$\sqrt{\quad}$ (—)	Flowrate @ S.T.P. Qm ($Ft.^3$/min.)
2.50	6.0	161.122	167.392	6.270	64.0	17.8	116	83	7:03.39	7.0565	0.68	15.284	0.99285	1.26111	0.85617
2.50	6.0	168.432	174.705	6.273	64.0	17.8	116	84	7:03.49	7.0582	0.76	15.284	0.99306	1.26227	0.85737
2.51	6.0	175.752	182.022	6.270	64.0	17.8	115	84	7:03.72	7.0620	0.77	15.284	0.99260	1.26478	0.85686
2.05	6.0	185.155	191.420	6.265	64.0	17.8	114	84	6:26.17	6.4362	0.85	15.284	0.99097	1.39327	0.93872
2.04	6.0	192.464	198.725	6.261	64.0	17.8	114	84	6:26.24	6.4373	0.83	15.284	0.99168	1.39100	0.93863
2.05	6.0	199.774	206.038	6.264	64.0	17.8	114	84	6:26.33	6.4388	0.86	15.284	0.99110	1.39327	0.93832

Linear Regression: Intercept (t) 0.0102

Slope (K) 0.6708

Coefficient of Determination (r^2) 0.9993

$\bar{\gamma}$ = 0.9947 ± 0.0027

$\Delta H@$ = 2.0424

Comments:

#245 Rev. 9/25/79 JF/cm

DRY GAS METER & ORIFICE METER CALIBRATION SHEET

1/2

Dry Gas Meter S/N Bendix 711030 — Lab No. 2c052

Atmospheric Pressure 29.25 in. hg or 743 mm hg — Calibrated by Jim Prokopowich & Jim Higham

Ambient Temperature 21.7 °C. — Date 7 Aug 85

Calibrated re Large Wet Test Meter

Manometer Orifice ΔH (in. H_2O)	W.T.M. Volume Vw ($Ft.^3$)	Dry Gas Meter Reading Initial ($Ft.^3$)	Dry Gas Meter Reading Final ($Ft.^3$)	D.G.M. Volume Vd ($Ft.^3$)	Temperature W.T.M. Tw (°F.)	Temperature W.T.M. Tw (°C.)	Temperature D.G.M. Ti (°F.)	Temperature D.G.M. To (°F.)	Time t (Min.:Sec.)	Time t (Min.)	W.T.M. Manometer Δm (in. H_2O)	Partial Pressure Ps (mm. Hg)	W.T.M.:D.G.M. Ratio γ (—)	$\sqrt{\quad}$ (—)	Flowrate @ S.T.P. Qm ($Ft.^3$/min.)
0.505	3.0	447.095	450.046	2.951	72.6	22.6	97	76	7:41.16	7.6860	0.35	20.565	1.0121	0.5650	0.3811
0.500	3.0	451.028	454.000	2.972	72.5	22.5	100	78	7.44.32	7.7387	0.46	20.441	1.0096	0.5633	0.3800
0.495	3.0	454.987	457.965	2.978	72.5	22.5	102	79	7.46.60	7.7667	0.46	20.441	1.0104	0.5610	0.3793
0.995	4.0	460.959	464.957	3.998	72.5	22.5	108	81	7:12.13	7.2022	0.53	20.441	1.0093	0.7963	0.5466
0.995	4.0	465.960	469.967	4.007	72.4	22.4	109	82	7:12.92	7.2153	0.51	20.316	1.0093	0.7970	0.5469
0.995	4.0	470.973	475.006	4.033	72.4	22.4	109	83	7:14.82	7.2470	0.53	20.316	1.0036	0.7978	0.5455
1.53	5.0	477.020	482.044	5.044	72.3	22.4	112	84	7:15.26	7.2543	0.54	20.316	1.0055	0.9895	0.6816
1.53	5.0	483.073	488.125	5.052	72.2	22.3	112	84	7:15.63	7.2605	0.54	20.193	1.0043	0.9895	0.6812
1.53	5.0	489.137	494.199	5.062	72.2	22.3	112	85	7:16.27	7.2712	0.52	20.193	1.0032	0.9904	0.6815
2.00	5.0	497.233	502.301	5.068	72.1	22.3	113	85	6.25.20	6.4200	0.74	20.193	1.0014	1.1317	0.7707
2.00	5.0	503.316	508.387	5.071	72.1	22.3	113	85	6.25.58	6.4263	0.60	20.193	1.0011	1.1317	0.7702
2.00	5.0	509.398	514.467	5.069	72.1	22.3	113	86	6.25.36	6.4227	0.60	20.193	1.0024	1.1328	0.7711

Linear Regression: Intercept (b) 0.0118

Slope (K) 0.6672

Coefficient of Determination (r^2) 0.9990

$\bar{\gamma}$ = 1.0042 ± 0.0042

ΔH@ = 2.0644

Comments:

F245 Rev. 9/29/85 JP/cm

DRY GAS METER & ORIFICE METER CALIBRATION SHEET

Lab No 20052

2/2

Dry Gas Meter S/N Bendix 711030

Calibrated re Large Wet Test Meter

Atmospheric Pressure 29.25 in. Hg = 743 mm. Hg

Calibrated by Jim Prokopovich & Jim Higham

Ambient Temperature 21.7 °C.

Date 7 Aug 85

Manometer Orifice ΔH (in. H_2O)	W.T.M. Volume Vw ($Ft.^3$)	Dry Gas Meter Reading Initial ($Ft.^3$)	Dry Gas Meter Reading Final ($Ft.^3$)	D.G.M. Volume Vd ($Ft.^3$)	Temperature W.T.M. Tw (°F.)	Temperature W.T.M. Tw (°C.)	Temperature D.G.M. Ti (°F.)	Temperature D.G.M. To (°F.)	Time t (Min.:Sec.)	Time t (Min.)	W.T.M. Manometer Δm (in. H_2O)	Partial Pressure Ps (mm. Hg)	W.T.M.:D.G.M. Ratio γ (—)	$\sqrt{\quad}$ (—)	Flowrate @ S.T.P. Qm ($Ft.^3$/min.)
2.52	6.0	517.511	523.597	6.086	72.0	22.2	114	86	6:56.57	6.9428	0.67	20.070	1.0017	1.2707	0.8561
2.50	6.0	524.615	530.708	6.093	72.0	22.2	114	86	6:56.88	6.9480	0.82	20.070	1.0002	1.2657	0.8552
2.50	6.0	531.724	537.826	6.102	72.0	22.2	114	86	6:57.22	6.9537	0.67	20.070	0.9991	1.2657	0.8548
3.00	6.0	540.874	546.960	6.086	72.0	22.2	114	86	6:23.24	6.3873	0.79	20.070	1.0002	1.3856	0.9292
3.00	6.0	547.975	554.068	6.093	71.9	22.2	114	87	6:23.41	6.3902	0.81	20.070	1.0001	1.3869	0.9306
3.00	6.0	555.083	561.171	6.088	71.8	22.1	114	87	6:23.31	6.3885	0.78	19949	1.0013	1.3869	0.9312

Linear Regressions: Intercept (b) 0.0118

Slope (K) 0.6672

Coefficient of Determination (r^2) 0.9990

$\bar{\gamma}$ = 1.0042 ± 0.0042

$\Delta H@$ = 2.0644

Comments:

#225 Rev. 9/29/83 JP/cm

S-TYPE PITOT TUBE CALIBRATION

PROBE SIZE (ft) 3 CALIBRATION # 85 - 19

PROBE LINER SS DATE March 19, 1985

PROBE MANUFACTURER RAC

TIP SIZE (inches) 0.375

TIP TYPE SS

STACK THERMOCOUPLE ☒ PRESENT

☐ ABSENT

HP 97 INPUT/OUTPUT

Temp	20.4	°C
Bar. Press	29.21	In. Hg
Scale Factor	0.1	

1.65	Δ p (std)	
27.357095		
2.74	Δ p (s-pitot)	
0.774069		
27.362828		

3.42	Δ p (std)	
39.385926		
5.55	Δp(s-pitot)	
0.783032		
39.394180		

0.20	Δ p (std)	
Tunnel Velocity 9.524518	ft/sec	
0.32	Δ p (s-pitot)	
Cp, at this 0.788593	velocity	
Tunnel Velocity 9.526514	(using Cp)	

1.92	Δ p (std)	
29.510639		
3.18	Δ p (s-pitot)	
0.775086		
29.516824		

3.90	Δ p (std)	
42.059132		
6.30	Δp(s-pitot)	
0.784829		
42.067947		

0.72	Δ p (std)	
18.071502		
1.22	Δ p (s-pitot)	
0.766301		
18.075289		

2.44	Δ p (std)	
33.257711		
4.04	Δ p (s-pitot)	
0.775206		
33.274683		

0.777195	Cp (ave)	
0.007453	Std. Dev.	
8	Deg. of Freedom	

1.21	Δ p (std)	
23.427217		
2.04	Δ p (s-pitot)	
0.768229		
23.432126		

2.90	Δ p (std)	
36.268284		
4.75	Δ p (s-pitot)	
0.779408		
36.275885		

2.306	t .05
0.771466	Low Cp
0.777195	Mean Cp
0.782924	High Cp

rev. 82-01

S-TYPE PITOT TUBE CALIBRATION

PROBE SIZE (ft) 3 CALIBRATION # 85 - 20

PROBE LINER 55 DATE March 19, 1985

PROBE MANUFACTURER RAC

TIP SIZE (inches) 0.500

TIP TYPE SS

STACK THERMOCOUPLE ☒ PRESENT

☐ ABSENT

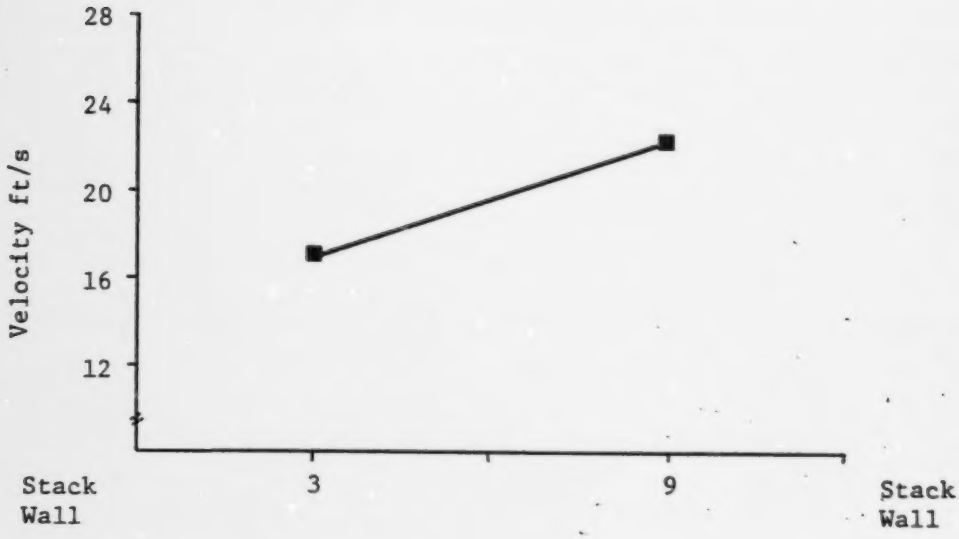
HP 97 INPUT/OUTPUT

Temp	20.4	°C		0.52	Δ p (std)	1.34	Δ p (std)
Bar. Press	29.21	In. Hg		15.357824		24.653603	
Scale Factor	0.1			0.84	Δ p (s-pitot)	2.10	Δp(s-pitot)
				0.784829		0.796812	
				15.361042		24.658770	
	0.12	Δ p (std)		0.60	Δ p (std)	1.72	Δ p (std)
Tunnel Velocity	7.377660	ft/sec		16.496949		27.931369	
	0.20	Δ p (s-pitot)		0.94	Δ p (s-pitot)	2.68	Δp(s-pitot)
Cp, at this	0.772660	velocity		0.796938		0.799116	
Tunnel Velocity	7.379206	(using Cp)		16.500406		27.937223	
	0.22	Δ p (std)		0.78	Δ p (std)		
	9.989399			18.809416			
	0.34	Δ p (s-pitot)		1.24	Δ p (s-pitot)	0.791782	Cp (ave)
	0.802389			0.791133		0.008986	Std. Dev.
	9.991492			18.813358		8	Deg. of Freedom
	0.35	Δ p (std)		1.00	Δ p (std)		
	12.599753			21.297470		2.306	t .05
	0.56	Δ p (s-pitot)		1.58	Δ p (s-pitot)	0.784875	Low Cp
	0.788593			0.793568		0.791782	Mean Cp
	12.602393			21.301933		0.798689	High Cp

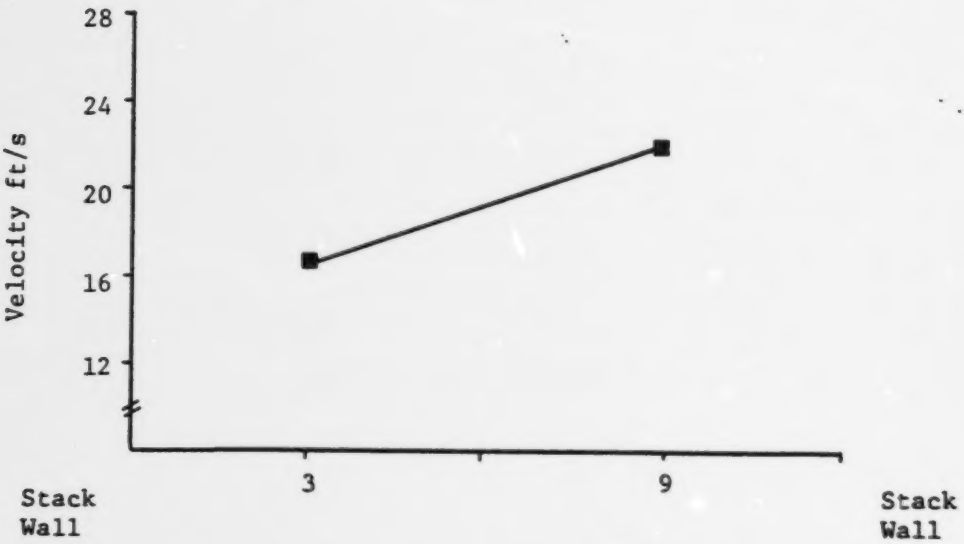
rev. 82-01

APPENDIX B: VELOCITY PROFILES

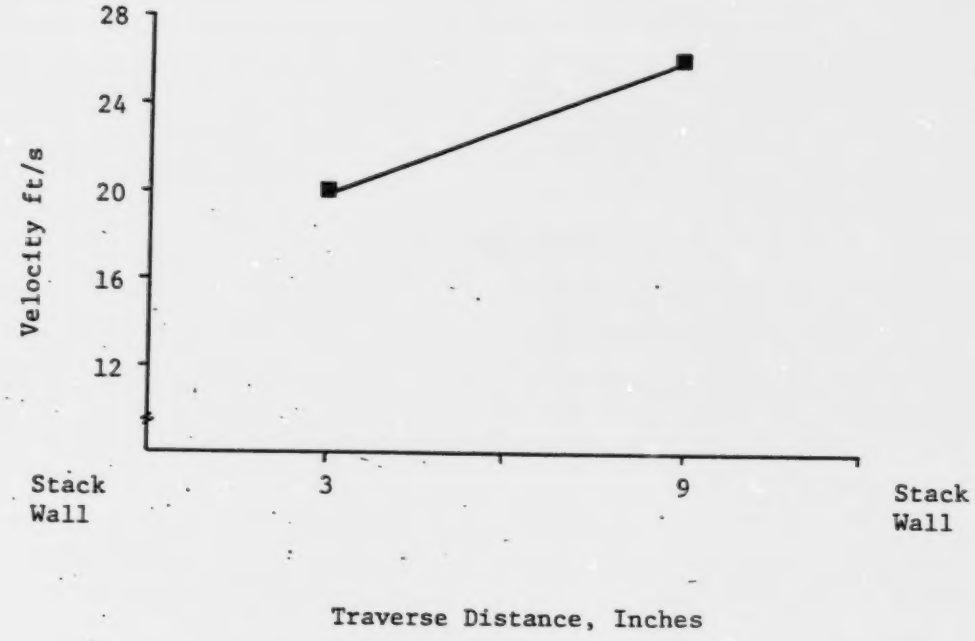
Graph 1. Velocity Profile of Test 1. Port 1.



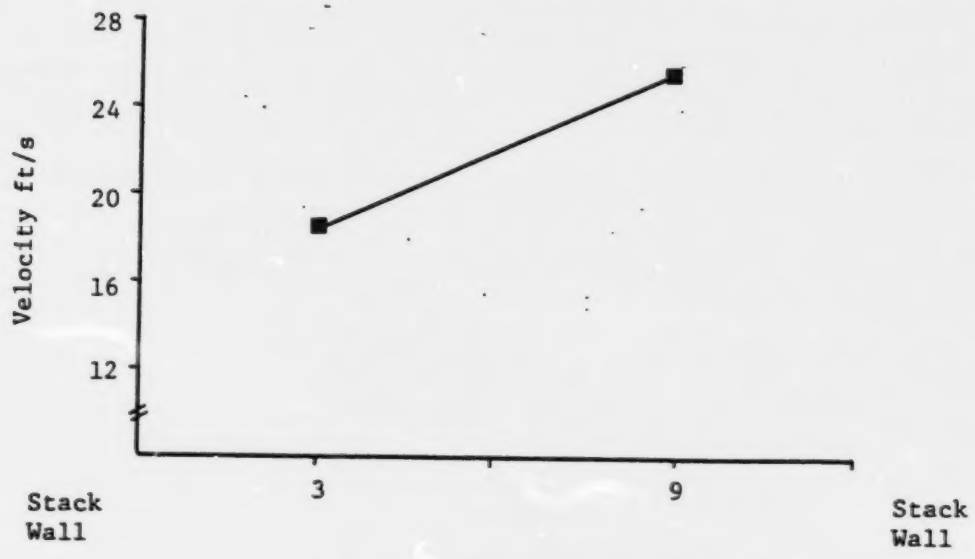
Graph 2. Velocity Profile of Test 1. Port 2.



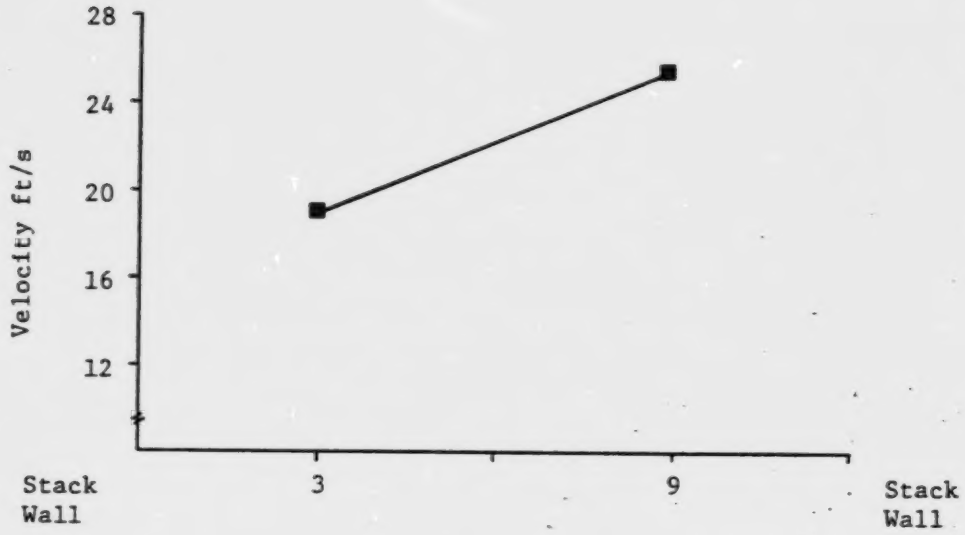
Graph 3. Velocity Profile of Test 2. Port 1.



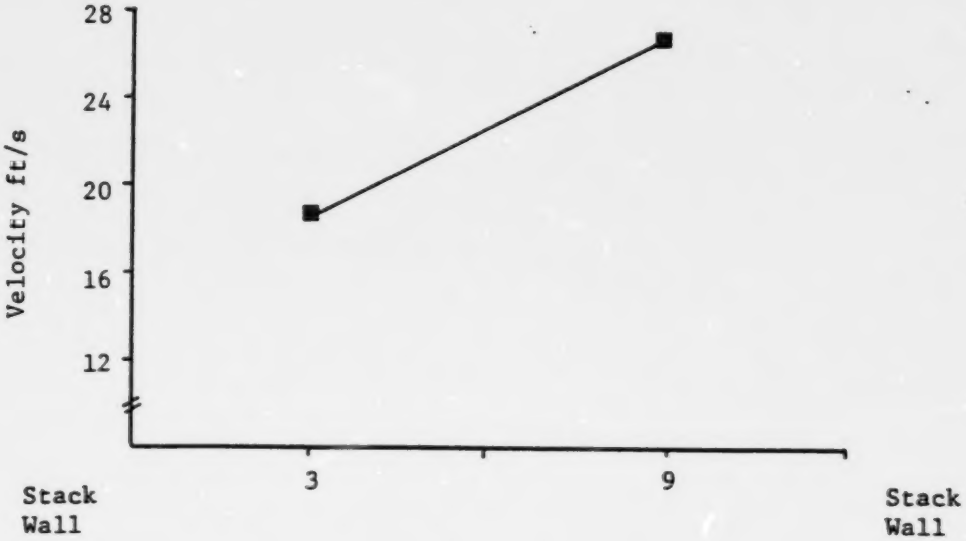
Graph 4. Velocity Profile of Test 2. Port 2.



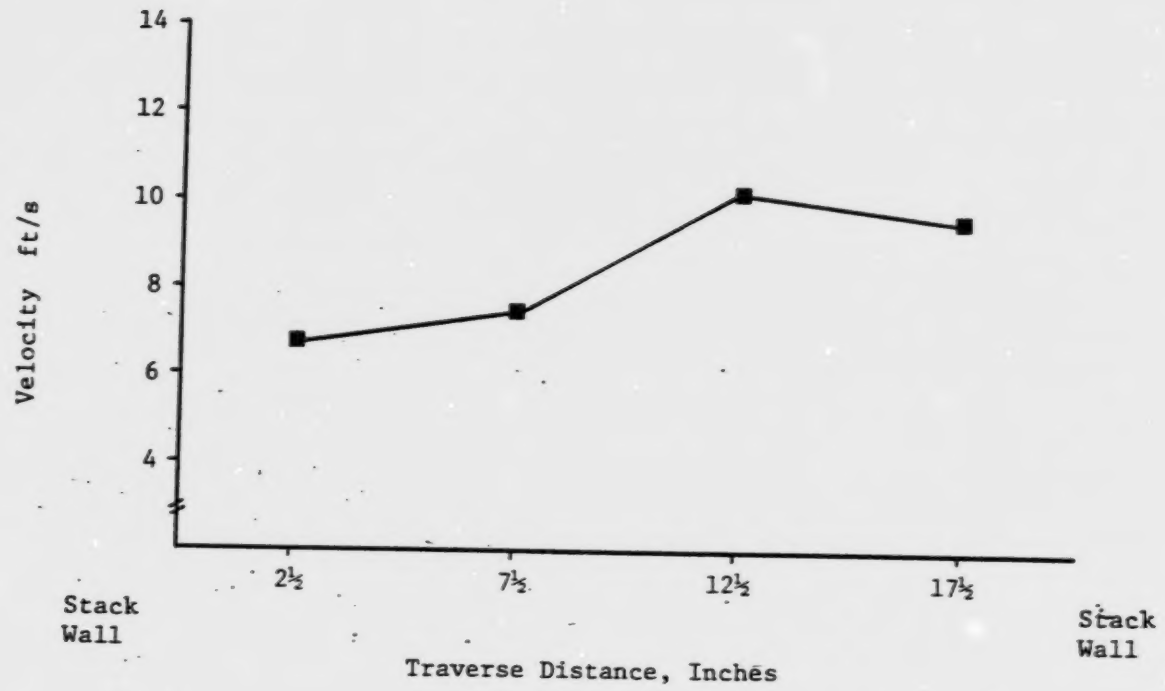
Graph 5. Velocity Profile of Test 3. Port 1.



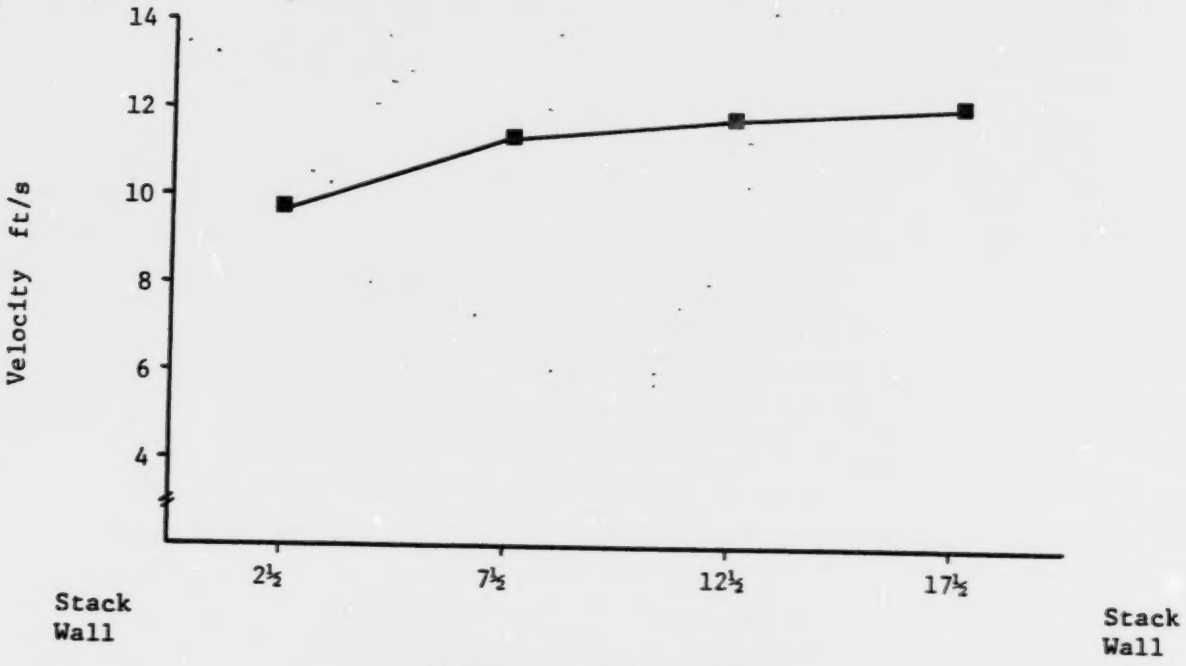
Graph 6. Velocity Profile of Test 3. Port 2.



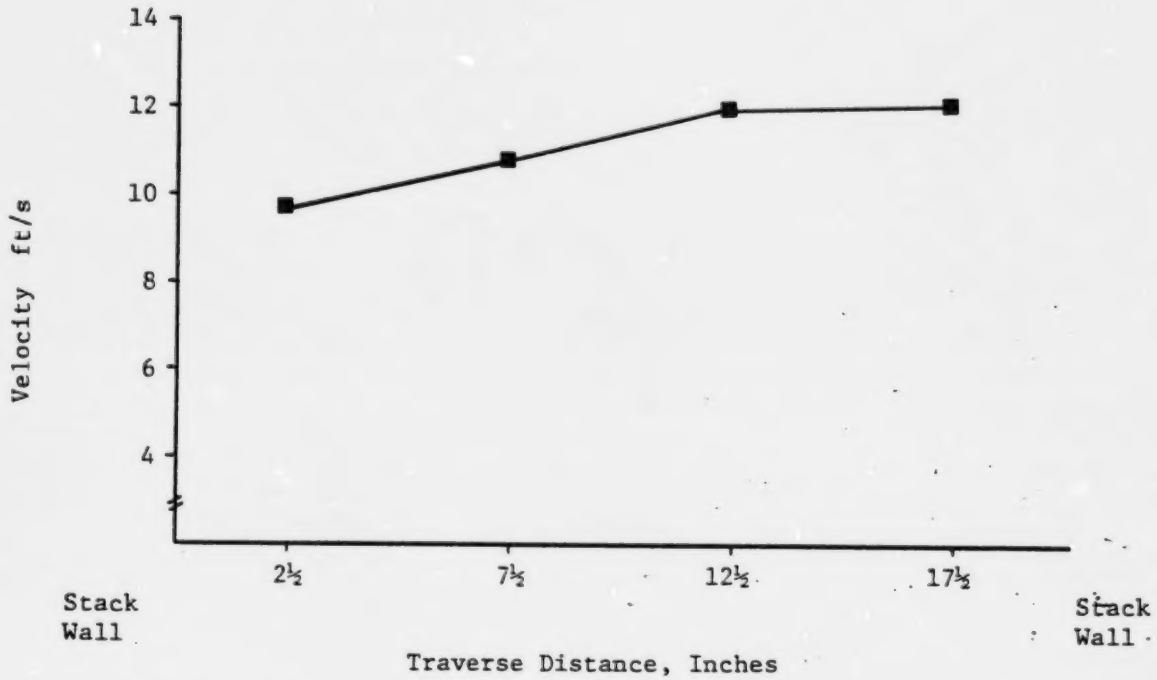
Graph 7. Velocity Profile of Test 4. Port 1



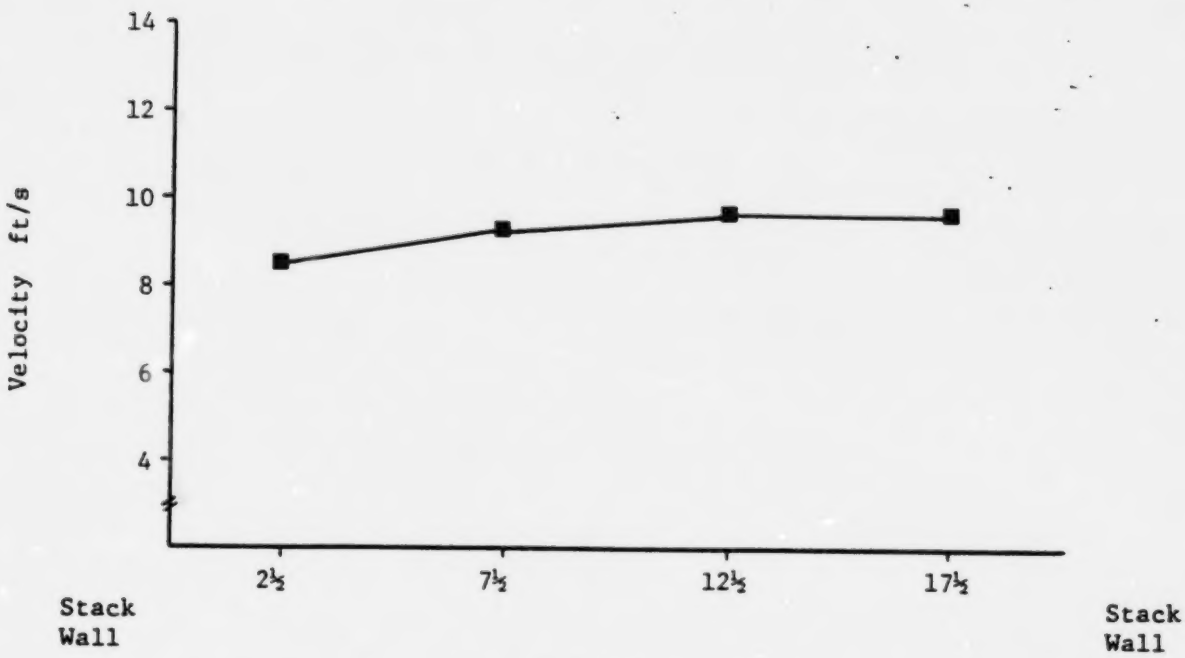
Graph 8. Velocity Profile of Test 4. Port 2



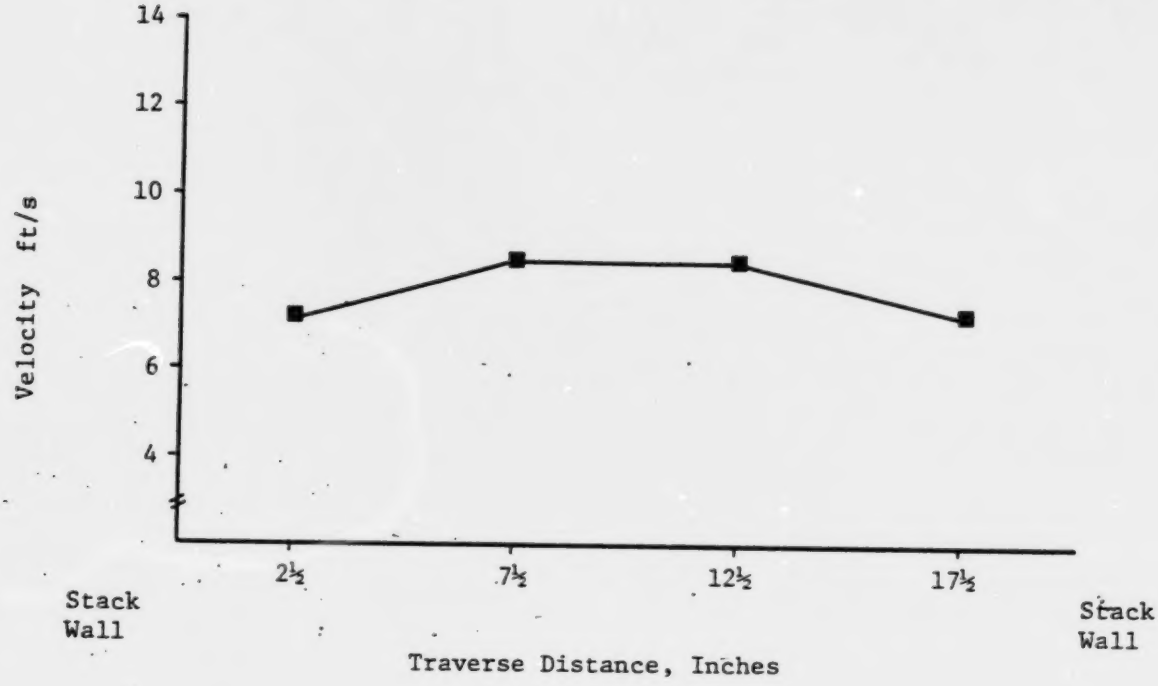
Graph 9. Velocity Profile of Test 4. Port 3



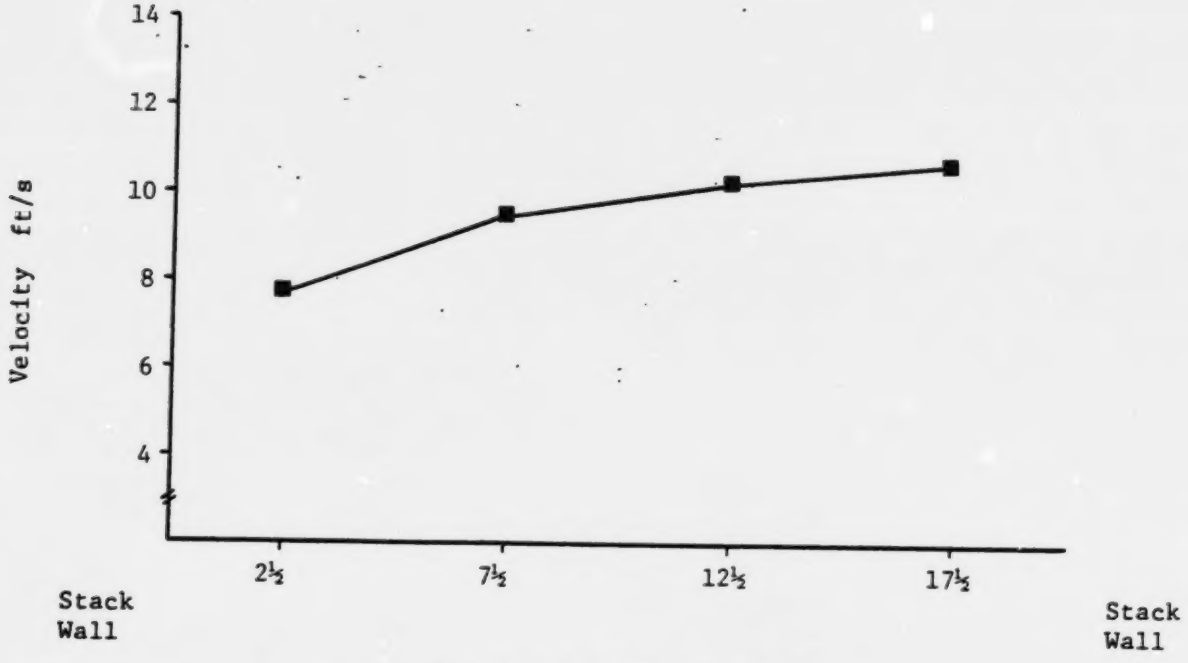
Graph 10. Velocity Profile of Test 4. Port 4



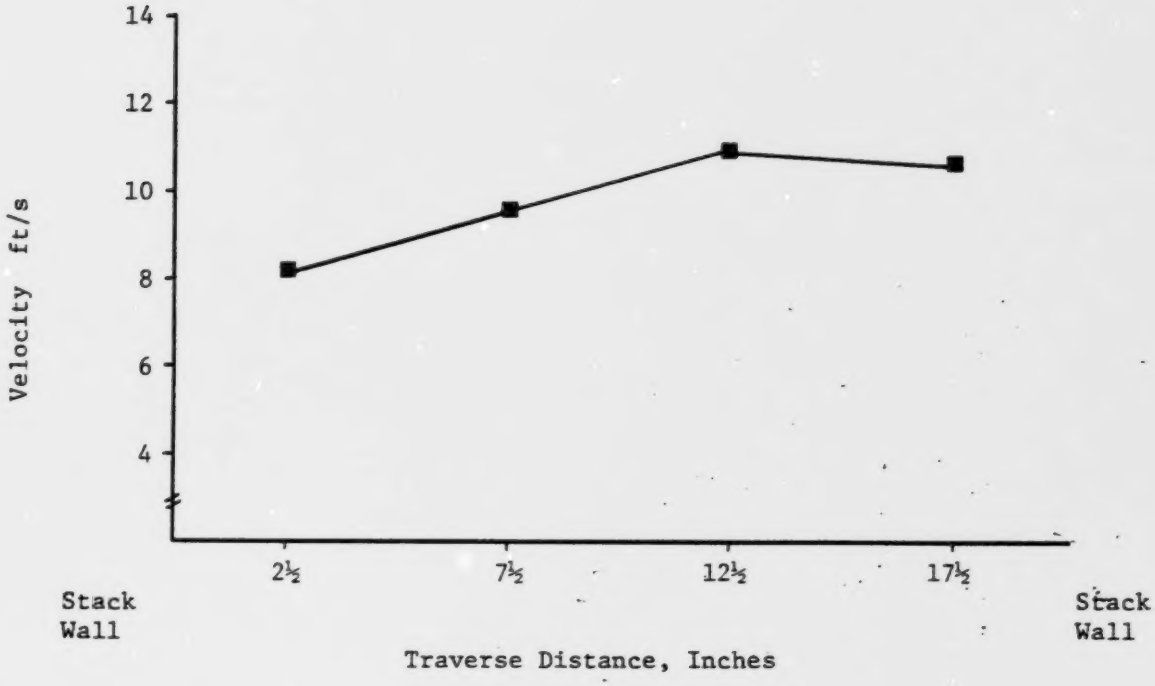
Graph 11. Velocity Profile of Test 5. Port 1



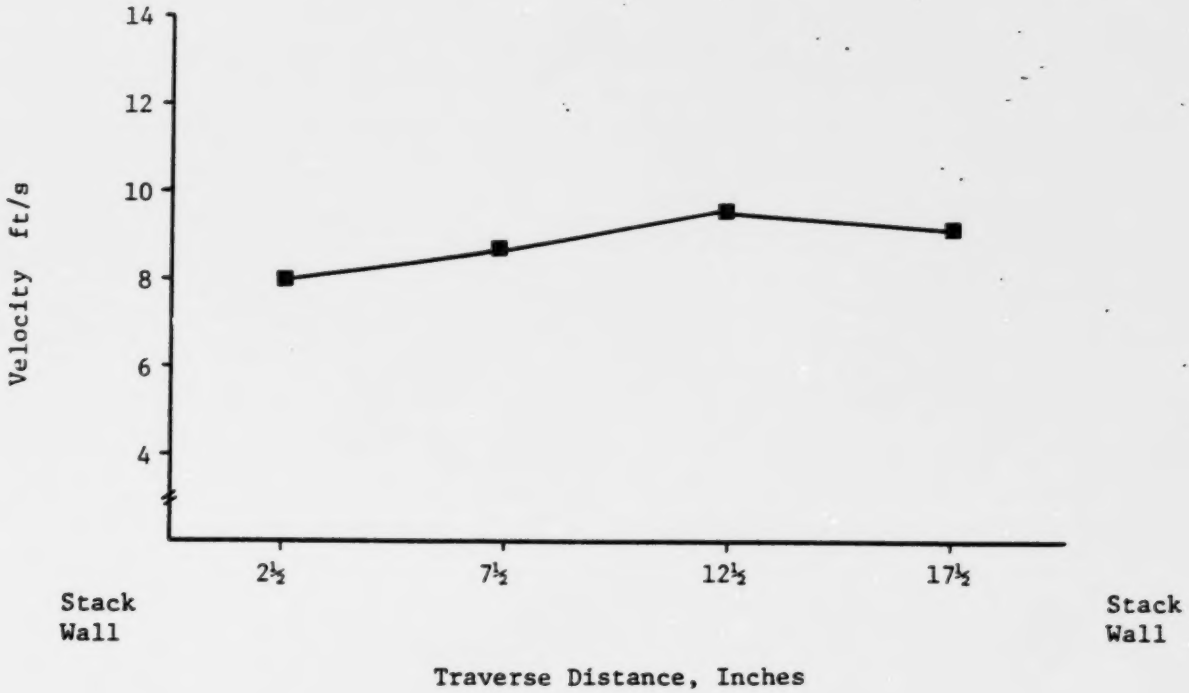
Graph 12. Velocity Profile of Test 5. Port 2



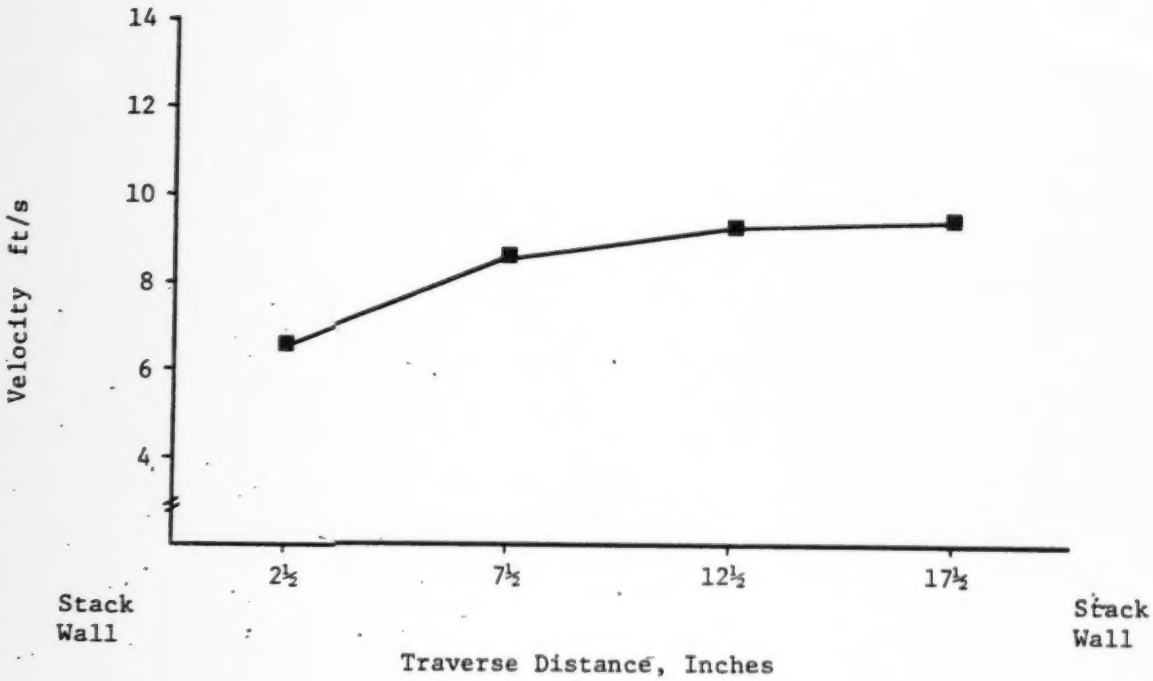
Graph 13. Velocity Profile of Test 5. Port 3



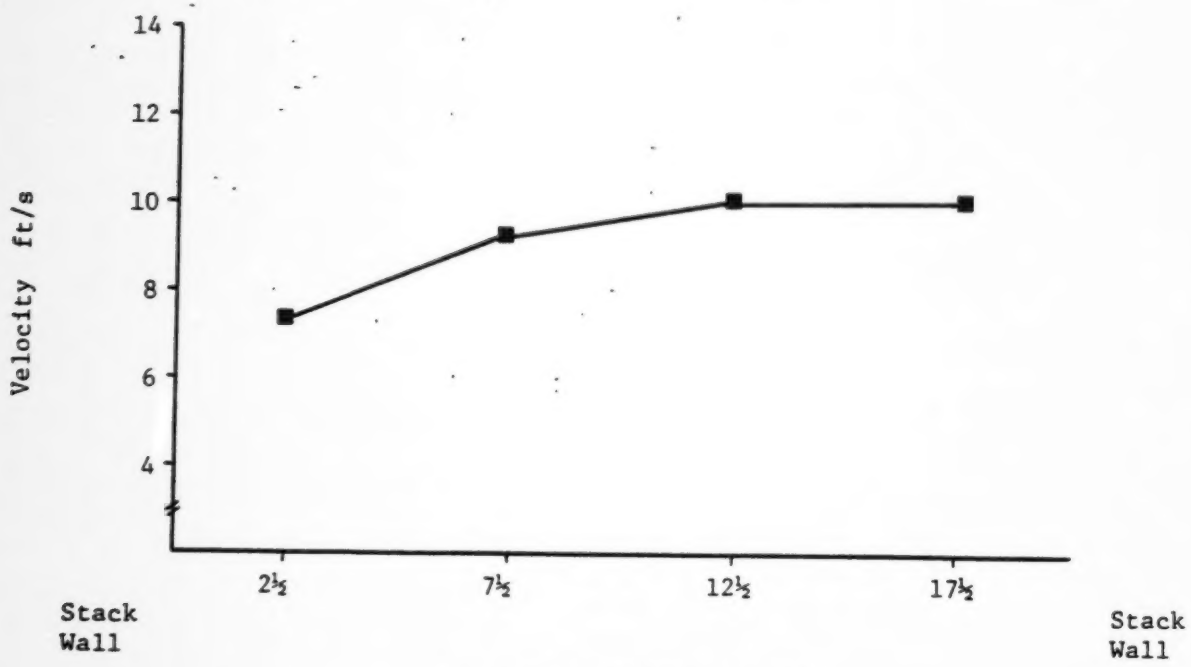
Graph 14. Velocity Profile of Test 5. Port 4



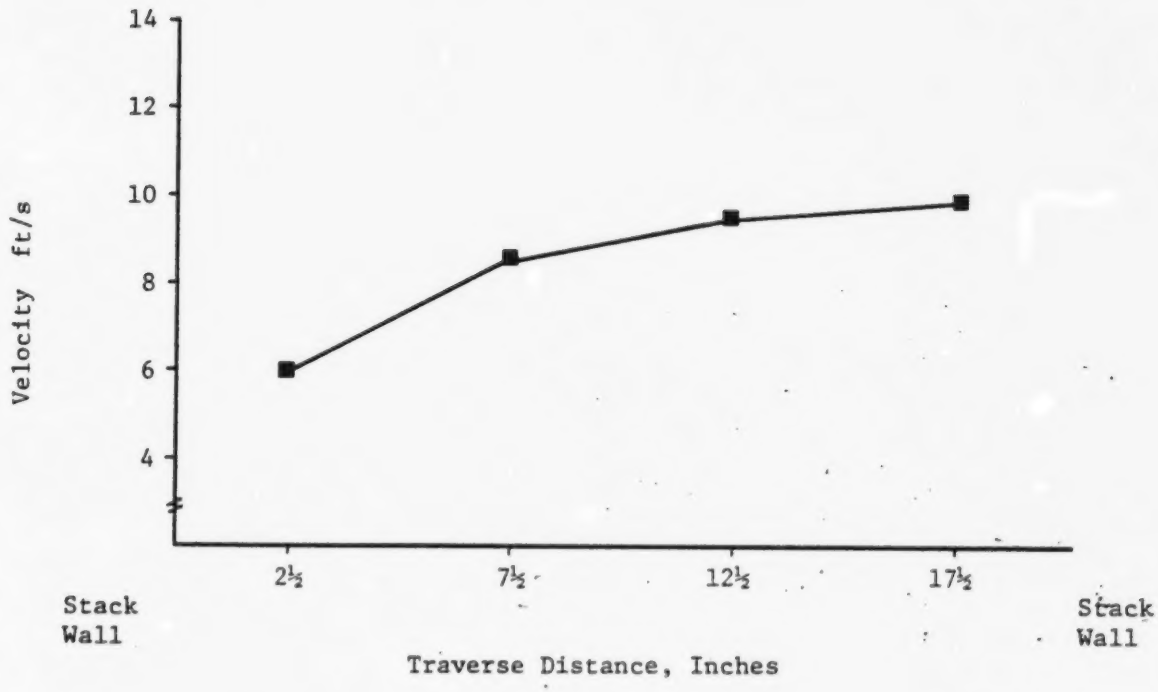
Graph 15. Velocity Profile of Test 6. Port 1



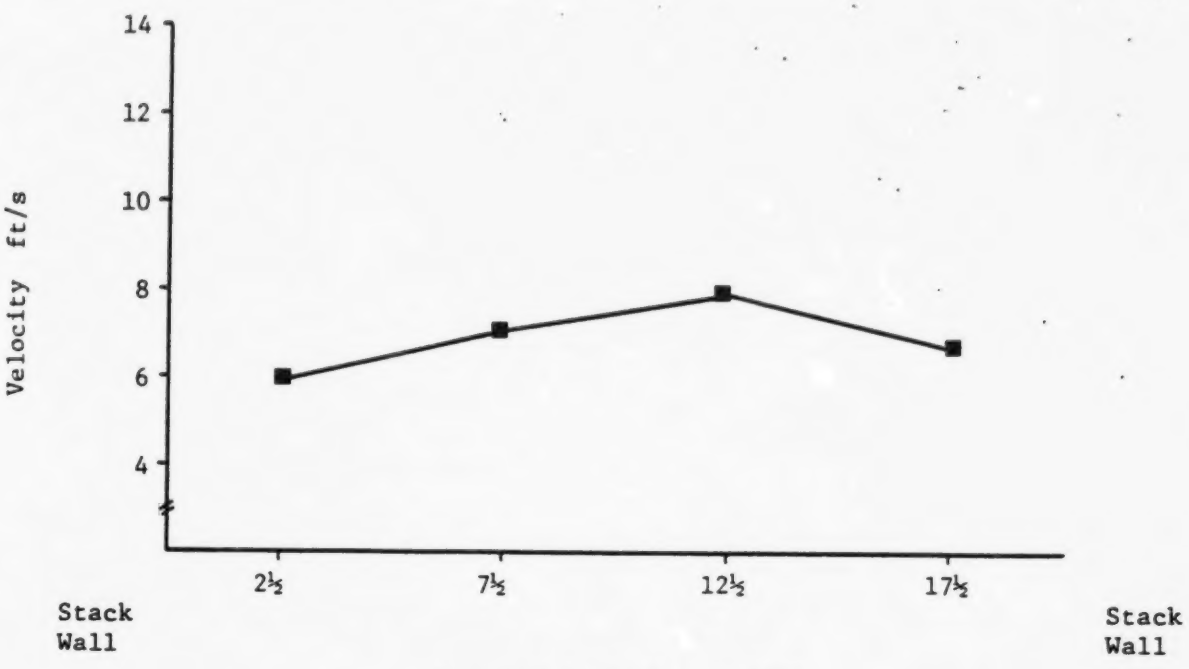
Graph 16. Velocity Profile of Test 6. Port 2



Graph 17. Velocity Profile of Test 6. Port 3



Graph 18. Velocity Profile of Test 6. Port 4



APPENDIX C: FIELD DATA SHEETS

FIELD DATA SHEET

Plant Pyrolysis Furnace at Hamblin Engineering Company **Location** 320 Osborne Street, Winnipeg, Manitoba

Stack 12" square **Test number** 1 **Date** June 19, 1985

Ambient temperature (°F) - **Barometric pressure (in. Hg)** 29.19 **Time** 9:56 A.M. to 10:19 A.M.

Nozzle diameter (in.) 0.497 **Probe length/type** 3 ft/stainless steel **Stack static pressure (in. H_2O)** +0.03

Probe temperature (°F) 251 (ave.) **Filter holder temperature (°F)** 249 (ave.) **Leak check** 0.001 **CFM @** 15" **Hg Vacuum**

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	446	4.143	0.06	2.28	89	79	73	13	106.8
2	5	468	5.032	0.10	3.34	90	80	89	15	102.0
2 - 1	10	453	3.979	0.06	2.05	100	81	89	8	106.5
2	15	482	5.017	0.10	3.35	105	82	89	16	103.5
Average or total	20	462	18.171	0.08	2.76	-	-	-	-	104.7

FIELD DATA SHEET

Plant Pyrolysis Furnace at Hamblin Engineering Compan **Location** 320 Osborne Street, Winnipeg, Manitoba

Stack 12" square **Test number** 2 **Date** June 19, 1985

Ambient temperature (°F) - **Barometric pressure (in. Hg)** 29.19 **Time** 11:45 A.M. to 12:07 P.M.

Nozzle diameter (in.) 0.366 **Probe length/type** 3 ft/stainless steel **Stack static pressure (in. H_2O)** + 0.03

Probe temperature (°F) 246 (ave.) **Filter holder temperature (°F)** 261 (ave.) **Leak check** 0.001 **CFM @** 15 **" Hg Vacuum**

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	533	2.521	0.08	0.750	104	92	83	4	110.2
2	5	554	3.084	0.13	1.23	111	92	70	5	104.6
2 - 1	10	533	2.262	0.07	0.645	112	92	90	4	105.5
2	15	563	3.034	0.12	1.16	118	92	75	5	105.2
Average or total	20	546	10.901	0.10	0.95	-	-	-	-	106.4

FIELD DATA SHEET

Plant Pyrolysis Furnace at Hamblin Engineering Company **Location** 320 Osborne Street, Winnipeg, Manitoba

Stack 12" Square **Test number** 3 **Date** June 19, 1985

Ambient temperature (°F) - **Barometric pressure (in. Hg)** 29.19 **Time** 12:37 P.M. to 12:59 P.M.

Nozzle diameter (in.) 0.366 **Probe length/type** 3 ft/ stainless steel **Stack static pressure (in. H_2O)** + 0.03

Probe temperature (°F) 254 (ave.) **Filter holder temperature (°F)** 259 (ave.) **Leak check** 0.000 **CFM @** 15 **" Hg Vacuum**

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	537	2.319	0.07	0.699	110	98	74	3	103.4
2	5	567	2.996	0.12	1.13	118	96	72	3	104.4
2 - 1	10	541	2.204	0.06	0.617	116	97	81	3	104.0
2	15	571	2.941	0.12	1.09	122	97	86	3	103.5
Average or total	20	554	10.460	0.09	0.88	-	-	-	-	103.8

FIELD DATA SHEET

Plant Pyrolysis Furnace at Hamblin Engineering Company **Location** 320 Osborne Street, Winnipeg, Manitoba

Stack 34 x 20" rectangular **Test number** 4 **Date** August 19, 1985

Ambient temperature (°F) 65 **Barometric pressure (in. Hg)** 29.36 **Time** 10:19 A.M. to 11:53 A.M.

Nozzle diameter (in.) 0.500 **Probe length/type** 3 ft./stainless steel **Stack static pressure (in. H_2O)** + 0.03

Probe temperature (°F) 266 (ave.) **Filter holder temperature (°F)** _____ **Leak check** 0.002 **CFM @** 15 **" Hg Vacuum**

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	235	2.010	0.012	0.569	88	82	59	3	98.1
2	5	218	2.305	0.015	0.732	95	80	54	4	99.0
3	10	298	2.820	0.025	1.10	101	79	55	5	99.3
4	15	348	2.458	0.020	0.817	104	80	59	5	99.7
2 - 1	20	365	2.472	0.021	0.846	104	84	55	4	98.8
2	25	395	2.810	0.028	1.10	108	85	51	5	97.7
3	30	417	2.985	0.030	1.15	111	85	52	5	101.9
4	35	442	2.939	0.030	1.11	112	87	53	5	101.1
3 - 1	40	400	2.391	0.020	0.768	102	89	51	4	99.3
2	45	408	2.725	0.025	0.974	106	88	51	4	101.5
Average or total										Cont'd...

TEST 4 Cont'd..

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. HgO	Isokinetic factor, %
						Inlet	Outlet			
3	50	433	2.925	0.029	1.09	106	88	52	5	102.7
4	55	434	2.918	0.029	1.09	106	87	53	5	102.5
4 - 1	60	356	2.207	0.016	0.648	99	88	51	4	99.5
2	65	353	2.540	0.020	0.835	102	87	51	4	103.1
3	70	414	2.400	0.020	0.757	106	87	54	4	100.0
4	75	414	2.402	0.020	0.759	109	89	55	4	99.8
Average or total	80	371	41.307	0.023	0.90	-	-	-	-	100.3

FIELD DATA SHEET

Plant Pyrolysis Furnace at Hamblin Engineering Company **Location** 320 Osborne Street, Winnipeg, Manitoba

Stack 34 x 20" Rectangular **Test number** 5 **Date** August 19, 1985

Ambient temperature (°F) 73 **Barometric pressure (in. Hg)** 29.36 **Time** 12:54 P.M. to 2:50 P.M.

Nozzle diameter (in.) 0.500 **Probe length/type** 3 ft/stainless steel **Stack static pressure (in. H_2O)** + 0.03

Probe temperature (°F) 246 (ave.) **Filter holder temperature (°F)** 255 (ave.) **Leak check** 0.002 **CFM @** 15 **" Hg Vacuum**

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	335	1.927	0.012	0.495	98	90	57	3	98.9
2	5	397	2.186	0.016	0.626	104	89	55	3	100.7
3	10	411	2.161	0.016	0.611	106	89	56	3	99.8
4	15	407	1.865	0.012	0.461	106	89	58	3	100.9
2 - 1	20	303	2.227	0.015	0.644	94	90	54	3	100.3
2	25	385	2.470	0.020	0.797	99	90	50	3	100.9
3	30	404	2.595	0.022	0.856	99	89	54	4	102.2
4	35	416	2.685	0.024	0.916	98	89	56	4	102.2
3 - 1	40	354	2.117	0.015	0.609	100	88	54	3	97.7
2	45	397	2.420	0.020	0.784	104	88	55	4	99.1
Average or total										Cont'd...

- TEST 5 - cont'd.

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F Inlet	Gas meter temperature, °F Outlet	Final impinger Temperature, °F	Pump vacuum in. Hg.	Isokinetic factor, %
3	50	424	2.707	0.025	0.947	99	89	54	4	100.5
4	55	430	2.661	0.024	0.904	98	89	56	4	101.4
4 - 1	60	370	2.023	0.014	0.560	93	91	52	2	97.9
2	65	365	2.285	0.017	0.703	99	90	50	3	100.6
3	70	418	2.405	0.020	0.759	102	88	50	4	100.0
4	75	413	2.278	0.018	0.687	104	88	53	4	99.1
Average or total	80	389	37.012	0.018	0.710	-	-	-	-	100.1

FIELD DATA SHEET

Plant Pyrolysis Furnace at Hamblin Engineering Company **Location** 320 Osborne Street, Winnipeg, Manitoba

Stack 34 x 20" rectangular **Test number** 6 **Date** August 21, 1985

Ambient temperature (°F) 65 **Barometric pressure (in. Hg)** 29.28 **Time** 9:52 A.M. to 11:30 A.M.

Nozzle diameter (in.) 0.500 **Probe length/type** 3 ft/stainless steel **Stack static pressure (in. H_2O)** + 0.03

Probe temperature (°F) 271 (ave.) **Filter holder temperature (°F)** 290 (ave.) **Leak check** 0.001 **CFM @** 15 **" Hg Vacuum**

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F		Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
						Inlet	Outlet			
1 - 1	0	349	1.683	0.010	0.410	75	70	60	3	100.1
2	5	379	2.135	0.016	0.632	85	70	55	4	100.2
3	10	419	2.235	0.018	0.683	90	70	56	4	101.3
4	15	422	2.308	0.019	0.717	93	70	57	4	101.5
2 - 1	20	396	1.857	0.012	0.472	88	72	60	2	101.6
2	25	431	2.235	0.018	0.683	93	74	58	4	101.9
3	30	456	2.350	0.020	0.739	96	74	58	4	102.3
4	35	463	2.349	0.020	0.731	98	75	59	4	102.6
3 - 1	40	365	1.521	0.008	0.330	87	78	60	2	99.6
2	45	447	2.040	0.015	0.559	95	79	58	3	101.8
Average or total										cont'd...

TEST 6 cont'd.

Traverse point number	Clock time, start	Stack gas temperature, °F	Gas meter volume, cu. ft.	Velocity pressure, in. H_2O	Orifice pressure drop in. H_2O	Gas meter temperature, °F Inlet	Gas meter temperature, °F Outlet	Final impinger Temperature, °F	Pump vacuum in. Hg	Isokinetic factor, %
3	50	464	2.250	0.018	0.664	100	80	58	4	103.0
4	55	441	2.428	0.020	0.764	102	80	59	4	103.9
4 - 1	60	365	1.542	0.008	0.332	94	82	60	2	100.1
2	65	438	1.660	0.010	0.375	97	82	60	2	100.2
3	70	422	1.940	0.013	0.501	100	82	59	3	101.7
4	75	417	1.617	0.009	0.347	98	81	60	2	101.1
Average or total	80	423	32.150	0.015	0.559	-	-	-	-	101.4

APPENDIX D: ANALYTICAL REPORT

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER:	KEVIN REEVE
LOCATION:	HUMBLIN ENGINEERING
REPORT TO:	KEVIN REEVE
STACK EMISSIONS TEST #1	EPA-1

SAMPLE – ID: From Y 85 Sequent 16267 To Y 85 Sequent 16269

L – Less than
G – Greater than

Date Sampled: Y 85 M 06 D 19

Date Received: Y 85 M 06 D 20

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
16267	BOTTLE #1	TSP		.0.0.6.3.	g	850624
16268	BOTTLE #2	TSP		.0.0.9.5.	g	850624
16269	FILTER # 438	TSP		.0.0.5.9.	g	850624

Date 6/27/85

Chemist Signature

WM. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE
LOCATION: HAMBLIN ENGINEERING
REPORT TO: KEVIN REEVE
STACK EMISSIONS TEST #2 EPI-1

From SAMPLE - ID: Y 85 Sequent 16270
To: Y 85 Sequent 16272

L – Less than
G – Greater than

Date Sampled: Y 85 M 6 D 19
Date Received: Y 85 M 06 D 24

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
16270	BOTTLE #1	TSP		.0.0.2.3	g	6.24
16271	BOTTLE #2	TSP		.0.1.3.7	g	6.24
16272	FILTER #439	TSP		.0.1.6.6	g	6.24

Date 8/27/85

Chemist Signature

WM. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE
LOCATION: HUMBLIN ENGINEERING
REPORT TO: KEVIN REEVE
STACK EMISSIONS TEST # 3 EPA

SAMPLE – ID
From Sequent: 85 16273
To Sequent: 85 16275

L – Less than
G – Greater than

Date Sampled: CY 85 M 06 D 07
Date Received: CY 85 M 06 D 25

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
16273	BOTTLE #1	TSP		0.0101.0	g	8706.27
16274	BOTTLE #2	TSP		0.0103	g	8706.27
16275	FILTER #440	TSP		0.0447	g	8706.27

Date 8706.27

Chemist Signature

W.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE ARC EX-1
LOCATION: HAMBLIN ENGINEERING TEST #4
REPORT TO: KEVIN REEVE ARC

From SAMPLE – ID: Y 85 Sequent 21296
To: Y 85 Sequent 21298

L – Less than
G – Greater than

Date Sampled: Y 85 M 08 D
Date Received: Y 85 M 09 D 03

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
21296	PROBE WASHINGS & GLASSWARE BEFORE FILTER	TSP		0.0257	g	08/28/85
21297	IMPINGER #1+#2	TSP		0.0272	g	"
21298	FILTER # 455	TSP		0.0269	g	"
~~21299~~						

Chemist Signature _____ Date 8-30-85

WM. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE ER-1
LOCATION: HAMBLIN ENGINEERING TEST #5
REPORT TO: KEVIN REEVE
ARC

From SAMPLE – ID: Y 85 Sequent 21,299
To: Y 85 Sequent 21,391

L – Less than
G – Greater than

Date Sampled: Y 85 M 05 D 19
Date Received: Y 85 M 06 D 23

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
21299	WASHINGS	TSP		0.0288	g	8/6/26
21300	IMPINGER #1 & #2	TSP		0.0142	g	
21301	FILTER #456	TSP		0.027	g	

Chemist Signature: [signature] Date: 8/6/26

MG 2832(o) 07/82 5M (B)

R.M. WARD TECHNICAL SERVICES LABORATORY CHEMICAL ANALYSIS FORM II

SUBMITTER: KEVIN REEVE
LOCATION: HAMBLIN ENGINEERING TEST #6
REPORT TO: KEVIN REEVE
ATC EX-1

SAMPLE – ID: From Y 85 Sequent 21302 To Y 85 Sequent 21304

L – Less than
G – Greater than

Date Sampled: Y 85 M 08 D 21
Date Received: Y 85 M 08 D 27

Sample Number	Identification or Comments	Parameter	L/G	Value	Units	Date Analyzed
21302	IMPINGERS	TSP		0.0101	g	85 09 13
21303	IMPINGERS #1+#2	TSP		0.0298	g	"
21304	FILTER #457	TSP		0.0117	g	"

Chemist Signature: [signature] Date: 9-6-85